STUDY ON CAR-TO-CAR SIDE IMPACT

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ABSTRACT

This paper studies the factors which affect the occupant injuries in Car-to-Car side impacts using CAE simulation .

The parameters of CAE simulation were derived from US-SINCAP(Side Impact New Car Assessment Program) test conditions and the field accident statistical data of NASS(National Automobile Sampling System).
The parameters varied in the CAE simulation were as follows:
1)   Striking vehicle curb weight
2)   Collision speed
3)   Ground clearance
4)   Front profile
5)   Vehicle width
And the comparing factors are Thorax injury severity (Thorax Trauma Index, TTI)and Pelvis injury severity (PELVIC G) as occupant protection of driver or passenger in the front seat position.

These studies make it possible to analyze directions for compatibility studies on side impacts including SUV (Sports Utility Vehicles), and these results are introduced herein. In addition, the occupant protection of a vehicle which obtained a result of TTI = 56G in the SINCAP test against a SUV was also analyzed and presented.

INTRODUCTION

SINCAP tests currently being carried out by NHTSA (National Highway Traffic Safety Administration)in the U.S. are MDB (Moving Deformable Barrier) tests which take into account car-to-car side impact accidents. (Fig. 1)
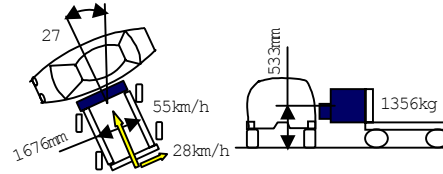

Figure 1. NHTSA SINCAP TESTING.

In addition, the MDB used in this test is a standardized MDB which is based on the average of various different types of striking vehicles.
However, the number of SUV sold in the U.S. has been rising in recent years, and particular focus is being placed on the increased damage to passenger cars in side impact accidents between SUV and passenger car. Therefore, striking vehicles were considered from a macroscopic viewpoint, and the relationships between the five factors of the striking vehicle curb weight, collision speed, ground clearance, front profile and vehicle width and injury severity of struck vehicles were investigated to analyze the main factors causing this increased damage.

SIMULATION STUDY

1. Effect of the Striking Vehicle Curb Weight

Fig. 2 shows a comparison of striking vehicle curb weight derived from side impact accident (including SUV) data (NASS CDS 95-97) in the U.S. and SINCAP test conditions.
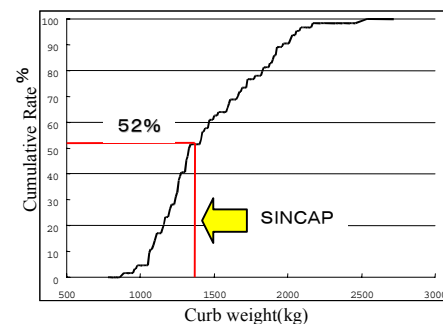

Figure 2. Weight Distribution   NASS CDS 95~97.

These results show that the SINCAP test conditions of MDB weight covers a cumulative rate of 52% in the accidents of striking vehicle curb weight. Accordingly, it is considered necessary to investigate curb weights of up to 2500 kg in order to cover approximately 100% of all accidents with this type of statistical analysis. Therefore, CAE simulations were conducted with varying SINCAP MDB weight to analyze the effects of MDB weight on injury severities (TTI, PELVIC G). (Fig. 3)

Note that for the simulation conditions, a Honda vehicle (mid-size 4-door sedan) was selected as the struck vehicle.
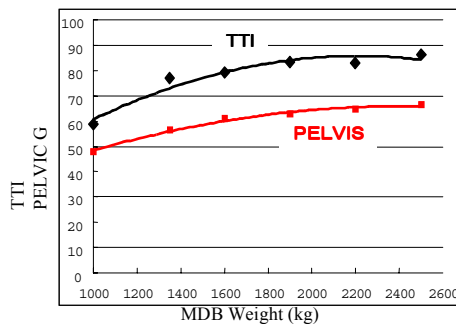

Figure 3. Injury Severity for MDB Weight.

These results show that the striking vehicle curb weight has some effect on passenger injury severity, and that the occupant injury severity changes as a logarithmic function which approaches a constant value at MDB weight over approximately 2000 kg.

2. Effect of Collision Speed

There is very little collision speed data in the U.S., so accident data presented at the 8th ESV Conference was compared with the SINCAP test condition. (Fig. 4)
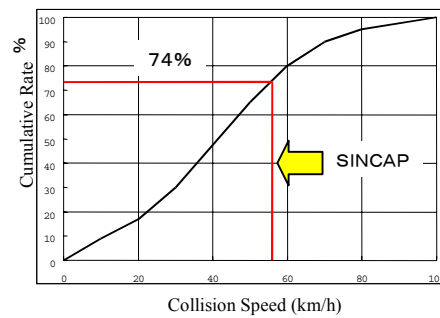

Figure 4. Speed Distribution 8th ESV.

These results show that the SINCAP test condition of MDB speed covers a cumulative rate of 74% in the collision speed of accidents. Accordingly, it is considered necessary to investigate speeds up to 100 km/h in order to cover approximately 100% of all side impact speeds. Therefore, CAE simulation analyses were conducted with varying MDB speed of SINCAP in the same manner as for curb weight. (Fig. 5)
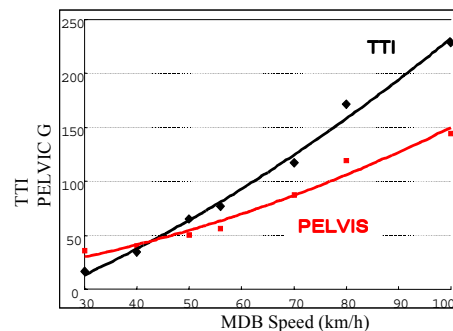

Figure 5. Injury Severity for MDB Speed.

Based on these results, collision speed has a significant effect on occupant injury severity, and injury severity is found to increase as a quadratic function with respect to speed.

3. Effect of Striking Vehicle Ground Clearance
**   (Bumper, Side Frame)**

Fig. 6 shows a comparison of the ground clearance (bumper, height of side frame upper surface) of vehicles (including SUV) currently being driven in the U.S. and SINCAP test condition. Note that this survey

was based on actual in-house measurements, and that the cumulative number of units was estimated based on the U.S. vehicle sales (1995-99).
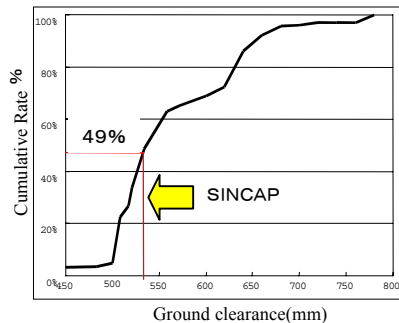

Figure 6. Height Distribution by In-house Research.

These results show that the SINCAP test condition covers a cumulative rate of 49% of striking vehicle ground clearances. Accordingly, it is considered necessary to investigate up to +220 mm higher than the current MDB position in order to cover approximately 100% of all accidents. Therefore, CAE simulation analyses were conducted with varying MDB heights of SINCAP in the same manner as for curb weight. (Fig. 7)
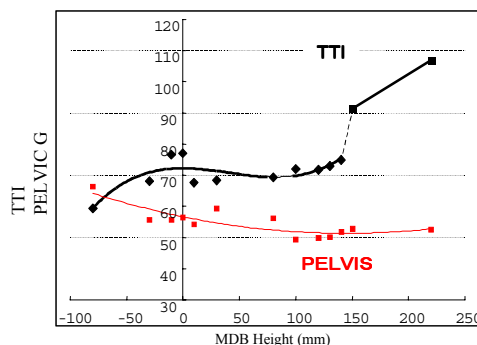

Figure 7. Injury Severity for MDB Height.

The results show some variance, but indicate that the striking vehicle ground clearance has a large effect on TTI. In addition, when the MDB height exceeds +140 mm, the center pillar buckles, causing the TTI to

increase rapidly. However, PELVIC G tends to decrease as ground clearance increases.
Therefore, these results show that the striking vehicle ground clearance has an extremely large effect on TTI.

4. Effect of Striking Vehicle Front Profile

Fig. 8 shows a comparison of the front profile of typical vehicles (including SUV) currently being driven in the U.S. and the MDB front profile of SINCAP. Note that this survey is based on actual in-house measurements. Also, the bumper and frame upper surface of the striking vehicle are shown aligned with the MDB.
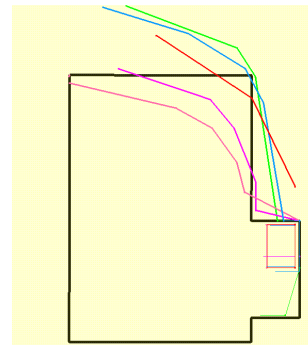

Figure 8. Comparison between `MDB and` Vehicle front profile`.`

This figure shows that many striking vehicles cannot be covered with only a flat front profile like the MDB. Therefore, CAE simulation analyses were conducted by varying the current MDB front profile. (Fig. 9)
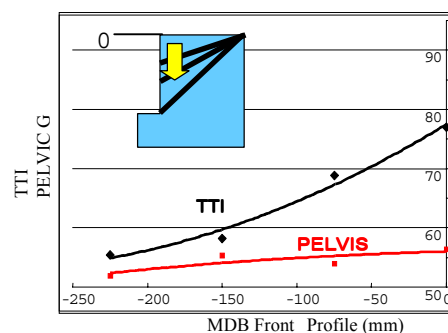

Figure 9. Injury Severity for MDB Front Profile.

The results show that TTI decreases as the front profile of the striking vehicle becomes sharper, and that changes in the front profile have little effect on PELVIC G.

5. Effect of Striking Vehicle Width

In actual accidents, the striking vehicles have various widths. Therefore, CAE simulation analyses were conducted by varying the current MDB width to analyze the effects of vehicle width. (Fig. 10)
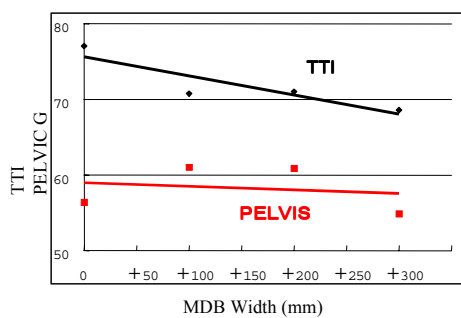

Figure 10. Injury Severity for MDB Width.

The results show significant variance, but TTI and PELVIC G both tend to increase as the MDB width becomes narrower.

6. Effect on Occupant Injury Severity

Fig. 11 summarizes the maximum variation for each of the parameters based on the above-mentioned results and using the results under SINCAP test condition as the reference (0).
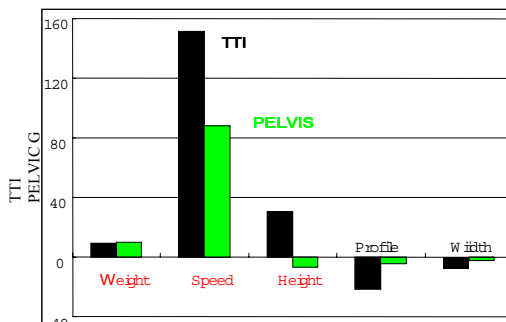

Figure 11.   Max.   Variation of Injury Severity.

Judging from these results, the only items greatly affecting injury severities (TTI, PELVIC G) are the three factors of speed, weight and height. Therefore, most actual side impact accidents can be reproduced by matching the MDB speed, weight and height to the striking vehicle.

7. Collision Tests Using Actual Vehicles

Honda and other companies in various countries are currently conducting side impact tests in which SUV are crashed into passenger cars. Therefore, the test results (NHTSA and in-house) for some mid-size sedan and various SUV were compared with the results of CAE simulation which matched the MDB to the speed, weight and ground clearance of the test vehicle (SUV). These results are shown in Figs. 12 and 13.
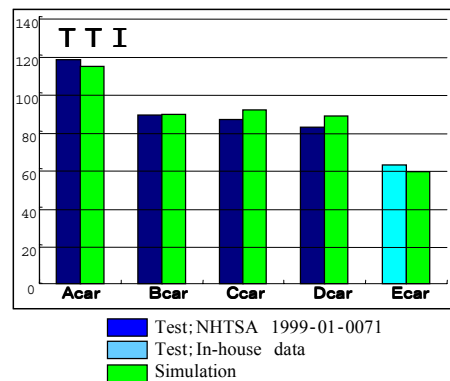

Test;NHTSA 1999-01-0071
Test;In-house data
Simulation

Figure 12. Comparison of Simulation and Test result for TTI.

Test;NHTSA 1999-01-0071
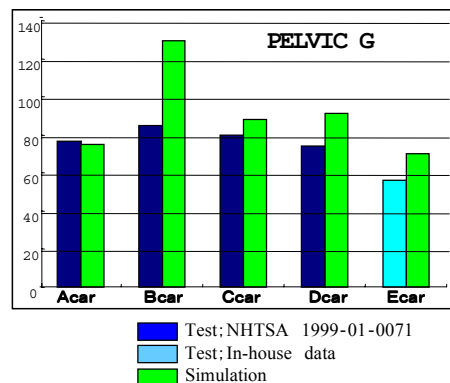Test;In-house data
Simulation

Figure 13. Comparison of Simulation and Test result for PELVIC G.

Although some results differed for some vehicles, it is found that overall trends could be adequately reproduced using this simulation method.

8. High-Speed MDB Collision Simulations

In order to investigate approximately 100% of all side impact accidents, three types of simulations from Case1 to Case3 are conducted using MDB with the speed, weight and height simultaneously changed from the prescribed values (55 km/h, 1360 kg, 530 mm) as shown in Fig. 14. In these simulations three different types of MDB were crashed into a vehicle (CAE model) which obtained a result of TTI = 56G in the SINCAP test.

Figure 14. Parameter Range of MDB.

The results show that both TTI and PELVIC G rise significantly as the speed increases. (Fig. 15)
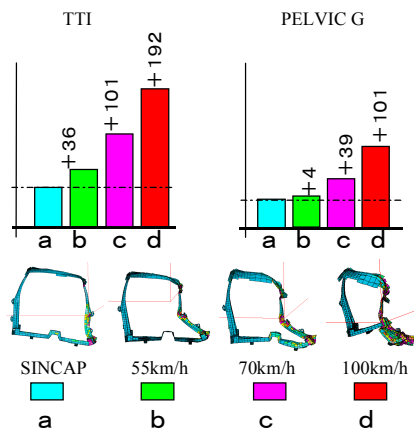

Figure 15. Simulation Result of High Speed Impact.

9. Occupant Protection of Current Vehicle

A parametric study with CAE simulation was conducted again for TTI to find out how much the curb weight and ground clearance of striking vehicle at a collision speed of 55 km/h affect the occupant protection of the above mentioned struck vehicle which has a performance of TTI = 56G in the SINCAP test. Note that the analysis was performed with criterion tentatively set at TTI = 72G or less. The results yield the relationship shown in Fig. 16.
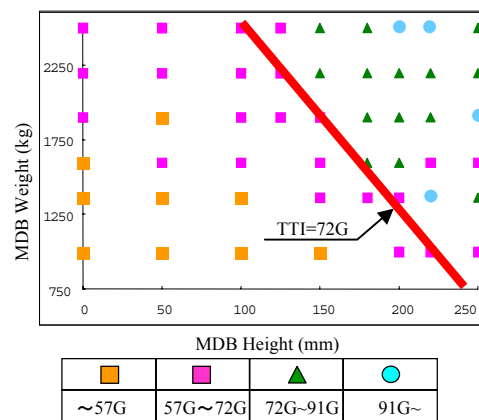

Figure 16. Relations of TTI between MDB Weight and Height.

DISCUSSION

In this research it was analyzed which factors of the striking vehicle affects the injury severity of the occupant in the struck vehicle by using a specific struck vehicle.
The following research are still to be conducted.

1) Research of differently constructed vehicles
2) Research of the injury severity of EU and JAPAN test methods

And head injury severity which results from contacting the striking vehicle directly is very challenging research but it also should be analyzed.

CONCLUSION

The following findings could be obtained from the parametric study performed herein;

It was found that the factors of the striking vehicle which influence the injury severities of TTI and PELVIC G were collision speed ,vehicle weight, and bumper or side frame height by CAE simulation study comparing with SINCAP test results.

  1)Striking vehicle weight
  Increasing the vehicle weight causes an increase in both TTI and PELVIC G on logarithmic curve.

  2)Impact velocity
   Increasing the impact velocity causes an increase in both TTI and PELVIC G on quadratic curve.

  3）Striking vehicle height
  If Center Pillar is buckled by the effect of striking vehicle height, the TTI will increase dramatically, but there is no such tendency on the PELVIC G.

REFERENCE

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